

AD- A136823

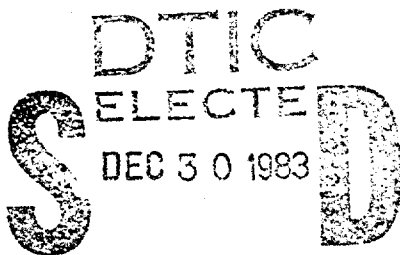
# Underwater Acoustics and the U.S. Navy: A Preliminary Historical Bibliography

Volume I: 1917-1946

J. A. S. PITTS

*NRL Historian*

December 16, 1983



Reproduced From  
Best Available Copy



NAVAL RESEARCH LABORATORY  
Washington, D.C.

Approved for public release; distribution unlimited.

DTIC FILE COPY

83 12 30 073

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM								
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER								
NRL Memorandum Report 5226	ADA136 823									
4. TITLE (and Subtitle)	5. TYPE OF REPORT & PERIOD COVERED									
UNDERWATER ACOUSTICS AND THE U.S. NAVY: A PRELIMINARY HISTORICAL BIBLIOGRAPHY Volume I: 1917-1946	Interim report on a continuing NRL problem.									
7. AUTHOR(s)	6. PERFORMING ORG. REPORT NUMBER									
J.A.S. Pitts										
9. PERFORMING ORGANIZATION NAME AND ADDRESS	8. CONTRACT OR GRANT NUMBER(s)									
Naval Research Laboratory Washington, DC 20375										
11. CONTROLLING OFFICE NAME AND ADDRESS	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS									
	72656-7101									
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	12. REPORT DATE									
	December 16, 1983									
	13. NUMBER OF PAGES									
	25									
	15. SECURITY CLASS. (of this report)									
	UNCLASSIFIED									
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE									
16. DISTRIBUTION STATEMENT (of this Report)										
Approved for public release; distribution unlimited.										
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)										
18. SUPPLEMENTARY NOTES										
Bibliography is planned as two volumes, so that Volume I can have unlimited distribution. Volume II will contain references to classified documents.										
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)										
<table border="0"> <tr> <td>History</td> <td>Anti-submarine warfare</td> </tr> <tr> <td>Bibliography</td> <td>Undersea warfare</td> </tr> <tr> <td>Underwater acoustics</td> <td></td> </tr> <tr> <td>Sonar</td> <td></td> </tr> </table>			History	Anti-submarine warfare	Bibliography	Undersea warfare	Underwater acoustics		Sonar	
History	Anti-submarine warfare									
Bibliography	Undersea warfare									
Underwater acoustics										
Sonar										
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)										
<p>Bibliography lists selected archival, manuscript, and published materials pertaining to underwater acoustics, sonar and non-acoustic submarine detection techniques. The lists are organized into six substantive categories. Within each category, the listings are grouped into four chronological sub-categories. Critical commentaries precede the listings in each category.</p>										

Accession For	
NTIS	GRA&I <input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	



## CONTENTS

INTRODUCTION .....	1
1. BIBLIOGRAPHIES .....	2
2. ARCHIVAL AND MANUSCRIPT SOURCES .....	3
3. HISTORICAL STUDIES .....	8
4. GENERAL, OFFICIAL AND POPULAR ACCOUNTS .....	11
5. SCIENTIFIC AND TECHNICAL REPORTS, STUDIES AND ASSESSMENTS .....	14
6. PRINCIPAL CONTRACTORS AND RESEARCH FACILITIES .....	22

UNDERWATER ACOUSTICS AND THE U.S. NAVY:  
A PRELIMINARY HISTORICAL BIBLIOGRAPHY

Volume I: 1917-1946

INTRODUCTION

This is a preliminary bibliography of selected archival, manuscript and published materials pertaining to the history of underwater acoustics research and sonar development in the U.S., 1917 to the present. It is the first of a series of products that will result from a long-term historical studies project being undertaken at the Naval Research Laboratory (NRL), Washington, D.C. It was compiled to serve as a working bibliography during the early stages of a long-term research project and, as such, is neither definitive nor all-inclusive. Nonetheless, the bibliography is unique\* and, for this reason, will be useful to other researchers interested in the subject. Ultimately, a final, critical bibliography will replace this preliminary bibliography.

Users of this bibliography should be aware that, in its current form, it is selective, rather than definitive. It was compiled to serve as a "working" bibliography for use in the early stages of a project to reconstruct and interpret the history of underwater acoustics and sonar development within the U.S. Navy and with particular reference to NRL. Accordingly, the selections emphasize R&D performed either within the Navy or under Navy sponsorship, and they give particular attention to work performed at NRL. Furthermore, the scientific and technical materials selected are not comprehensive or all-inclusive. The compiler selected those which, collectively, would reveal prevailing views and priorities at given times, the evolution of particular lines of research, and significant developments and changes of direction within the field.

The bibliography is also somewhat idiosyncratic, as it reflects the historical perspective and historical interests of the compiler. First, the bibliography emphasizes the literature of underwater acoustics as it pertained to submarine detection, even though acoustics research had other important applications (for example, acoustic torpedoes and mines). Second, the bibliography is not limited to materials directly related to underwater acoustics and sonar. Considerable space is given to the more general literature, which reveals the broader contexts within which underwater acoustics evolved, and to materials pertaining to physical oceanography and non-acoustic methods of submarine detection. Finally, the bibliography is organized by categories and sub-categories which are meaningful to the compiler; other forms of organization are possible.

The bibliography is being issued in two volumes. The second volume will be a preliminary bibliography of materials pertaining to undersea warfare R&D since 1946.

---

\* Extensive bibliographies have been prepared under the auspices of the National Academy of Sciences, the Office of Naval Research and others. However, these are technical bibliographies intended for use by researchers in acoustics. A British historian, Dr. Willem Hackmann has written a history of underwater acoustics in the Royal Navy, which is in press; however, his bibliography has not been available for review, and he does not plan to prepare and distribute a comprehensive bibliography.

Manuscript approved September 28, 1983.

## 1.0. BIBLIOGRAPHIES.

1.1. Comment. Since 1951, numerous bibliographies of underwater acoustics and undersea warfare R&D have been published. Annual bibliographies have appeared in the U.S. Navy Journal of Underwater Acoustics since 1951. In 1955, the Library of Congress, the Office of Naval Research (ONR) and the NRL cooperated in the compilation of a continuing bibliography, "Underwater Sound: An Annotated Bibliography." The first two volumes were published by the LoC and surveyed literature published from 1941-1955. Subsequent volumes, surveys of literature published after 1955, were published each 1-2 years through the early 1970s by ONR. In 1959, ONR began publishing a continuing series, "Undersea Warfare Research and Development: A Tripartite Bibliography." Finally, in 1957, the Committee on Undersea Warfare of the National Research Council, under ONR contract, published A Partial Bibliography on Undersea Warfare. Subsequent issues appeared on an irregular basis through 1974. All of these bibliographies are classified. With the exception of the NRC bibliography, they reference only published materials and technical reports prepared by contractor and Navy laboratories. Unpublished materials cited in the NRC bibliography are limited to those prepared by the Committee on Undersea Warfare.

1.2. The following bibliographies are guides to undersea warfare literature published before 1946. Bergman, Ultrasonics, is a textbook which contains a 1048-item bibliography. The entries pertain to one specialized area of acoustics, and less than 20% of the references relate to underwater acoustics. The Columbia University bibliography is an excellent guide to the published technical literature of underwater acoustics; however, it does not contain information on unpublished archival and manuscript materials. The bibliography compiled by the Committee on Undersea Warfare is exceptional in several ways: it traces the literature of the submarine to the late 1500s; it places strong emphasis on general materials (e.g., Congressional reports, popular articles, historical studies, etc.); it includes some references to manuscripts; and it identifies many useful articles which appeared in obscure and extinct publications. Its principal limitations are that it is skewed toward pro-submarine warfare and submarine technology, gives relatively little space to original scientific and technical studies (the entries for underwater sound are primarily articles written by non-specialists for reading by general audiences), and does not cite archival materials.

Bergmann, L. Ultrasonics. New York: John Wiley and Sons, 1939.

Bryce, Barbara A. An Annotated Literature Survey of Submarines, Torpedoes, Anti-Submarine Warfare, Undersea Weapons Systems and Oceanography, 1941-1962. Annapolis, Md.: Naval Institute Press, 1962.

Columbia University, Division of War Research. Bibliography and Brief Review of Published Material on the Physical Principles of Submarine Detection. New London, Conn. (OEMsr-20), Sept. 1941.

Committee on Undersea Warfare. An Annotated Bibliography of Submarine Technical Literature, 1557-1953. Washington: National Research Council-National Academy of Sciences, 1954.

Select List of References on Submarine Boats and Warfare. Washington: Library of Congress, Nr. 1, 1913; Nr. 2, 1917.

## 2.0. ARCHIVAL AND MANUSCRIPT SOURCES.

2.1. Comment. The vast majority of archival and manuscript materials pertaining to undersea warfare R&D are in files which are subsets of larger, more general records collections. The principal collections are in the National Archives, the Library of Congress, and the archives of the National Research Council. The following is a general listing of these collections. A detailed description and an assessment will be presented in a later, critical bibliography.

### 2.2. Before World War I.

- a. Navy Department, Historical Records, 1775-1911, Records Group 45 National Archives, Washington D.C.

Series B, "Ordnance," Subseries BM, "Mines and Torpedoes": 13 folders pertaining to submarine design and engineering.

Series K, "Nautical Science and Technology," Subseries KH, "Hydrography," 3 folders pertaining to acoustic and non-acoustic sounding techniques.

Series O, "Fleet Operations," Subseries ON, "Strategy and Tactics": 2 folders pertaining to use of submarines in fleet operations.

- b. Office of the Chief of Naval Operations, records of, 1882-1968, R.G. 38, National Archives.

### 2.3. World War I Era.

- a. Bureau of Ships (including Bureau of Engineering), records of, R.G. 19, Nat. Arch.

Materials on submarine design and engineering.

- b. Josephus Daniels Papers, Manuscripts Division, Library of Congress, Washington, D.C.

Materials pertaining to Naval Consulting Board and submarine/anti-submarine warfare, interfiled with other materials.

- c. Stanford C. Hooper Papers, Manuscripts Division, LoC.

Containers 39-40: Tape recordings of a "History of Sonar".

- d. National Research Council Archives, Academy of Sciences, Washington, D.C.

Comm. on Physics: Sub-Comm. on Submarine Detection, 1917: 11 Folders pertaining to acoustic and non-acoustic detection projects.

Comm. on Physics: Projects: Submarine Detection, 1918: 8 folders pertaining to submarine detection projects and reports.

Exec. Comm., 1915-1919: Correspondence and reports pertaining to NRC relations with contractors, universities, foreign governments and the Navy.

e. Naval Consulting Board, records of, R.G. 80, National Archives.

Boxes 19-24: Solicited and unsolicited ideas for inventions, some pertaining to anti-submarine warfare and submarine detection devices.

Box 32, Folder 3, & Box 33, Folder 1: Correspondence with Secretary of Navy re submarine warfare.

Boxes 41-43: Miscellaneous materials pertaining to anti-submarine warfare, particularly submarine chasers.

f. Naval Engineering Experiment Station, New London, Ct, Correspondence, Reports and Administrative Records of, R.G. 181, Acc. Nr. 10294, Federal Records Center, Suitland, Maryland (Erroneously filed as "Harvey Hayes Papers").

Approximately 20 cu. ft. of documents pertaining to submarine detection research and development, 1917-1920, and to the Navy Department Special Board on Anti-Submarine Devices. Documents are in 413 numbered folders.

g. Navy Department, Historical Records, 1911-1927, R.G. 45, National Archives.

Series L, "Strategy and Tactics," Sub-Series LA, "Anti-Submarine Warfare": Approximately 90 file folders pertaining to submarine detection devices and techniques.

Series C, H, I, J, O and P: Miscellaneous documents pertaining to submarine warfare interfiled with general materials on Navy operations, policies, facilities and regulations.

h. Office of the Chief of Naval Operations, records of, Operational Archives, Naval History Center, Washington, D.C.

Records of the Submarine Warfare Division, 1915-1952.

i. Office of Chief of Naval Operations, records of, 1382-1968, R.G. 38, National Archives.

j. Secretary of the Navy, records of, R.G. 80, National Archives.

Documents pertaining to submarine and anti-submarine warfare interfiled with correspondence and administrative records.

2.4. Inter-War Era, 1919-1939.

a. Harold G. Bowen Papers, Manuscripts Div., LoC.

b. Bureau of Ships, records of, R.G. 19, Nat. Arch.

Entries 993 & 994: "General Correspondence" and "Index to General Correspondence", both 1923-1940: 2400 cu. ft. Scattered references to submarine detection research and development.

Bureau of Ships, cont.:

Entry 1015: "Reports of Tests at the Naval Research Laboratory, 1933-1940": one-half cu. ft.

Entries 1016 -1021: Various reports and records of tests on vessels, including submarines, through 1939: 150 cu. ft.

- c. Josephus Daniels Papers, Manuscripts Div., LoC.
- d. General Board of the Navy, records of, Operational Archives, Naval History Center, Washington Navy Yard, Washington, D.C.
- e. Stanford Hooper Papers, Manuscripts Div., LoC.
- f. National Research Council Archives, National Academy of Sciences, Washington, D.C.  
  
Committee on Physical Sciences: Submarine Detection, 1919: 1 folder, summary report for General Board of Navy .  
  
Exec. Comm., 1919-1931: Government Agencies: Navy: 5 folders pertaining primarily to Navy interest in oceanography.  
  
Exec. Comm., 1923-1931: Committee on Oceanography: 4 folders pertaining to submarine topography and physical oceanography.
- g. Naval Research Laboratory, records of, R.G. 19, National Archives.

Unclassified Series:

Boxes 32-35: NRL Budgets, 1923-1941.

Boxes 99-102: Records of NRL Sound Division, 1923-1942.

Confidential Series:

Boxes 3-7: Monthly reports of Radio and Sound Divisions.

Box 10: Misc. materials on anti-submarine warfare.

Boxes 54-62: Records of the Sound Division, 1923-1942.

NOTE: Files are arranged in series based on original security classifications. All of the files have been declassified.

- h. Navy Department, Historical Records, 1911-1927, 1927-1942, R.G. 45, Nat. Arch.

Same series as described above.

- i. Edgar G. Oberlin Papers, Manuscripts Div., LoC.



- j. Office of Chief of Naval Operations, Operational Archives, Naval History Center, Washington, D.C.

Records of the Submarine Warfare Division, 1915-1952.

2.4. World War II Era, 1939-1945.

- a. Harold G. Bowen Papers, Manuscripts Div., Library of Congress.
- b. Bureau of Ships, records of, R.G. 19, National Archives.
- c. Vannevar Bush Papers, Manuscripts Div., Library of Congress.
- d. Julius A. Furer Papers, Manuscripts Div., Library of Congress.
- e. General Board of the Navy, records of, Operational Archives, Naval History Center, Washington, D.C.
- f. Naval Research Laboratory, records of, 1942-1946, R.G. 181, Federal Records Center, Suitland, Md.

Accession Nr. 10294, "Harvey Hayes Papers": Mislabeled file--see para. 2.3, "Naval Engineering Experiment Station."

Acc. Nrs. 7184 & 11704, Unclassified Administrative Records of NRL, 1923-1950: Primarily records of the period 1942-1950. Sound Division materials interfiled with general materials.

Acc. Nrs. 8018 and 11029: Confidential and Secret Administrative Records of the NRL, 1923-1946: The overall accessions remain classified; however, most of the file documents have been declassified.

Acc. Nr. 11704: Unclassified NRL Problems Files, 1923-1950: Primarily records of the period 1942-1950.

Boxes 93-95: Sound Division.

Acc. Nr. 8018: Confidential NRL Problem Files, 1923-1950: The overall accession remains classified; however, most of the documents have been declassified.

Boxes 54-61: Sound Division.

Acc. Nr. 71-A-1984: Miscellaneous Records of the Acoustics Division, 1947-1967: The accession includes approximately 1 cu. ft. of materials (primarily progress reports on Division activities) pertaining to the period 1942-1946, which are interfiled with more recent materials. These materials have been declassified, but they are filed with classified materials.

NOTE: NRL records in storage at Suitland, Maryland, are the property of the Laboratory and may not be used by outside researchers without the permission of the Commanding Officer. This requirement applies to unclassified, as well as classified, records.

g. Navy Coordinator of Research and Development, records of, R.G. 298, National Archives.

Series A, "Coordinator's Files," Sub-Series A-3, "Laboratories", Box 8, Folder A3-2, "NRL."

Series B, "National Defense Research Committee," Sub-Series B-2, "Committees", Box 21, Folders B2-13 &-13a, "Hydrophone Advisory Comm."; Box 24, Folders B2-28a, "Joint Bd. on Scientific Information," and B2-32, "Underwater Sound Measurements Advisory Committee"; Sub-Series B-5, "Reports", Box 30, "NDRC, Division C."

Series D, "Problems," Boxes 61-65, "Underwater Sound"; Boxes 96-101, "Sub-Surface Warfare."

h. Office of the Chief of Naval Operations, records of, Operational Archives, Naval History Center, Washington, D.C.

Records of the Central Division, 1941-1943.

Records of the Fleet Operations Division, 1944-1950.

Records of the Immediate Offices of the Chief of Naval Operations/Commander in Chief, U.S. Fleet.

Records of the Submarine Warfare Division, 1915-1952.

i. Office of the Commander in Chief, U.S. Fleet, records of, Operational Archives, Naval History Center, Washington, D.C.

Records of the Tenth Fleet, 1941-1946: includes records of the Anti-Submarine Warfare Operations Research Group.

Records of the New Weapons, Research, and Development Section, 1943-1945.

j. Office of Scientific Research and Development (including the National Defense Research committee and the National Research Council), R.C. 227, National Archives.

k. Secretary of the Navy/Chief of Naval Operations, Central Security-Classified Records, 1940-1947, R.G. 80, National Archives.

### 3.0. HISTORICAL STUDIES.

3.1. Histories of undersea warfare are numerous, but the vast majority are popular accounts of submarine development and pro-submarine warfare, written by non-historians, and intended for general audiences. The majority of these accounts either ignore underwater acoustics and related R&D or give it brief, superficial attention. Historical studies focused on underwater acoustics and sonar are few in number and are limited to the works of Hackmann (a professional historian), Lasky (a former Navy specialist in anti-submarine warfare policy and planning) and Klein (a former specialist in underwater sound). Hackmann's book, which is in press, will give some attention to developments in the U.S. Lasky's articles provide comprehensive reconstruction of the scientific and technical aspects and reveal a sincere attempt to relate these to broader historical issues.

### 3.2. General.

Cable, Frank T. The Birth and Development of the American Submarine. New York: Harper, 1924.

Hackmann, W.D. "Underwater Acoustics and the Royal Navy," Annals of Science 36 (1979), 255-278.

\_\_\_\_\_. Seek and Strike: Sonar, Underwater Warfare and the Royal Navy, 1914-1954. (In Press).

Howeth, L.S. History of Communication-Electronics in the U.S. Navy. Washington: BuShips and Office of Naval History, 1963, pp. 297-312, 471-478.

Hunt, Frederick V. Electroacoustics: The Analysis of Transduction, and Its Historical Background. Cambridge: Harvard University Press, 1954.

Klein, Elias. Notes on Underwater Sound Research and Applications before 1939. Washington: Office of Naval Research, Rpt. ACR-135, 1967.

Lake, Simon. The Submarine in Peace and War. Philadelphia: J.B. Lippincott, 1918.

Lasky, Marvin. "Review of Undersea Acoustics to 1950," Journ. Acoustical Soc. Am. 61 (1977), 283-297.

Lindsay, R.B. Acoustics: Historical and Philosophical Development. East Stroudsburg, Penna.: Douden, Hutchison and Ross, 1973.

Polmar, Norman. The American Submarine. Annapolis, Md.: The Nautical and Aviation Publishing Company of America, 1981.

### 3.3. Before World War I.

Batcheler, L.B. "When Sonar Was Called Submarine Signaling," Journ. Acoust. Soc. Am. 31 (1959): p. 832.

Field, Cyril. The Story of the Submarine from the Earliest Ages to the Present. London: S. Low, Marston and Company, 1908.

Fyfe, Herbert C. Submarine Warfare, Past and Present. London: E.G. Richards, 1907.

Hoar, Allen. The Submarine Torpedo Boat: Its Characteristics and Modern Development. New York: Van Nostrand, 1916.

Roland, Alex. Underwater Warfare in the Age of Sail. Bloomington: Indiana University Press, 1978.

Sueter, Murray F. The Evolution of the Submarine Boat, Mine and Torpedo, from the Sixteenth Century to the Present. Portsmouth, Eng.: J. Griffin and Co., 1907.

#### 3.4. World War I Era.

Jellicoe, John R. The Submarine Peril: The Admiralty Policy in 1917. London: Cassell & Co., 1934 (LC)

Lasky, Marvin. "Review of World War I Acoustic Technology," U.S.N. Journ. Underwater Acoustics 24 (July, 1973): 363-384.

#### 3.5. Inter-War Era, 1919-1939.

Hayes, Harvey C. "History of the Sound Division, NRL, 1917-1941," Unpublished ms. deposited in NRL Historical Collection.

Lasky, Marvin, "A Historical Review of Underwater Acoustic Technology, 1916-1939, with Emphasis on Undersea Warfare," U.S.N. Journ. Underwater Acoustics 24 (Oct. 1974): 597-623.

#### 3.6. World War II Era.

Farago, Ladislav. The Tenth Fleet. New York: Obolensky, 1962.

Furer, Julius A., "Scientific Research and Modern Warfare," U.S. Nav. Inst. Proc. 71 (Mar. 1945), 259-271.

Herrick, John. Subsurface Warfare: The History of Division 6, NDRC. Washington: DoD, Research and Development Bd., 1951.

Lasky, Marvin. "Review of Scientific Effort for Undersea Warfare, 1939-1945," U.S.N. Journ. Underwater Acoustics 25 (July 1975): 567-583.

\_\_\_\_\_, "Historical Review of Underwater Acoustic Technology 1939-1945, with Emphasis on Undersea Warfare," U.S.N. Journ. Underwater Acoustics (Oct. 1975): 885-918.

Morison, Samuel E. The Two Ocean War. Boston: Little, Brown, 1963.

Office of Naval Research. "History of Research and Development in World War II," unpublished manuscript in Operational Archives, Naval History Center.

Shea, T.E. and Glennan, T.K., "A Summary of the Work of the New London Laboratory on Equipment and Methods for Submarine and Subsurface Warfare, 1941-1945," NDRC No. 2337 (1945).

Sternhell, C.M. and Thorndike, A.M. Anti-Submarine Warfare in World War II. Operations Evaluation Gp. Rpt. Nr. 51. Washington: Navy Department/-Office of Chief of Naval Operations, 1946.

Survey of Subsurface Warfare in World War II. Summary Technical Report of Division 6, NDRC, Vol. I. Washington: Office of Scientific Research and Development, 1946.

#### 4.0. GENERAL, OFFICIAL AND POPULAR ACCOUNTS.

4.1. Comment. The submarine and its potential for undersea warfare has been a subject of concern to both public officials and popular writers since the early 1800s. Although most historically significant information pertaining to undersea warfare plans and policies is in archival and manuscript collections, some indications of official attitudes, as well as useful information on technology and fleet resources can be gained from published official reports. Books and articles intended for popular audiences reflect contemporary concerns about submarine warfare, and many include good discussions of submarine technology. As a rule, these general accounts give relatively little attention to anti-submarine warfare and present little information on related R&D.

#### 4.2. Before World War I.

Barber, Frances M. Lecture on Submarine Boats and Their Applications Newport, R.I.: U.S.N. Torpedo Station, 1875. (LoC).

Barnes, J.S. Submarine Warfare--Offensive and Defensive. n.p 1869.

Melville, G.W. "The Submarine Boat: Its Value as a Weapon of Naval Warfare," Annual Report, Smithsonian Institute, 1901, pp. 717-738.

Naval Mobilization and Improvement in Materiel, Office of Naval Intelligence General Information Series Nr. 8, Washington: Navy Department, 1889, pp. 438, 453-455.

Nimitz, Chester. "Military Value and Tactics of Modern Submarines," U.S. Nav. Inst. Proc. 38 (1912): 1193-1211.

U.S. Congress. House. Committee on Naval Affairs, Hearings ... on Submarine Boats, Washington: 1902.

U.S. Congress. Senate. Committee on Naval Affairs, Submarine Torpedo Boat Holland, Washington: 56th Congress, 1st Session, Senate Doc. 14, Serial 3844, 1899.

White, William. "Submarines," Sci. Am. 59 (1905): 24606-24607, 24630-24631; 60 (1905): 24689-24690, 24838-24839, 24933-24934.

#### 4.3. World War I Era.

Domville-Fyfe, Charles W. Submarine Engineering Today. Philadelphia: J.B. Lippincott, 1914.

\_\_\_\_\_. Submarines, Mines and Torpedoes in the War. London: Hodder and Stoughton, 1914.

Horsnall, W.O. "War beneath the Waves: Submarines, Torpedoes, Submarine Mines," Chamber's Journ. (London), Ser. 7, Vol. 5 (Mar-May 1915), 190-192, 198-200, 193-294.

"Is There any Defense against the Submarine?" Scientific American 112 (1915), p. 152.

Kearney, Thomas A. "The Submarine: Its Purpose and Development," U.S. Nav. Inst. Proc. 41(1915): 1239-1250.

Modern Submarine Warfare. Scientific American Special Issue, 7 November 1914.

National Research Council. The Submarine. Washington: Nat. Acad. Sci., 1918.

Newbolt, Henry. Submarine and Antisubmarine. London: Longmans, Green & Co., 1918.

U.S. Congress. House. Comm. on Naval Affairs, Hearings...on Estimates by the Secretary of the Navy, Washington: 1917.

U.S. Navy Department, Naval Consulting Board. The Enemy Submarine. New York: 1918.

U.S. Navy Department, Naval Consulting Board. The Submarine and Kindred Problems. New York: NCB Bull. Nr. 1, 1917.

#### 4.4. Inter-War Era, 1919-1939.

Baker, W.D. "Submarine Capabilities and Limitations," U.S.N. Nav. Inst. Proc. 51 (1925), 1398-1407.

Beach, Brewster. "Tracking Submarines," Pop. Mechanics 33 (Apr. 1920), 527-528.

\_\_\_\_\_, "Hunting Submarines with a Sound Detector," Sci. Am. 120 (1919), 335-353.

Boyle, R.W. "Ultrasonics," Science Progress 23 (1928), 75-105.

Ellsberg, Edward. Men under the Sea. New York: Dodd, Mead & Co., 1939.

Hubbard, J.C. Future Uses of the Submarine. Philadelphia: J.B. Lippincott, 1936.

Masters, D. The Submarine War. New York: Henry Holt & Co., 1935.

Spear, Lawrence, "The Submarine of Today," Trans. Soc. Naval Arch. and Marine Eng. 35 (1927), 55-71.

#### 4.5. World War II Era.

Barnes, Robert H. United States Submarines. New Haven, Conn.: H.F. Morse Assoc., 1945.

Chatterton, Edward. Fighting the U-Boats. London: Hurst and Blackett, 1942.

Domville-Fyfe, Charles W. Evolution of Sea Power. London: Rich and Crown, 1939.

Low, Archibald. The Submarine at War. New York: Sheriden House, 1942.

Roscoe, Theodore, U.S. Submarine Operations in World War II, Annapolis: US. Naval Institute, 1949.

"Submarine Warfare in 1917 and 1939," Engineering (Oct 1939), 410-412.

Woodbury, David O. What the Citizen Should Know about Submarine Warfare. New York: W.W. Norton, 1942.



## 5.0. SCIENTIFIC AND TECHNICAL REPORTS, STUDIES AND ASSESSMENTS.

5.1. Comment. The development of new and improved techniques and equipment for submarine detection was a top priority in undersea warfare R&D within the U.S. Navy through the end of World War II. The related R&D effort emphasized research in underwater acoustics and the application of this research to the development of acoustic detection devices. However, the Navy also supported research in non-acoustic areas, such as radio-electronics and electro-magnetism, and assumed that a diversity of detection techniques--both acoustic and non-acoustic--could be developed.

Technical documents pertaining to undersea warfare R&D before 1923 often are in the form of unpublished reports. These may be found in the referenced archival and manuscripts collections. Some technical surveys were published in scientific and engineering periodicals. Technical materials prepared after 1923 often are found as technical reports published by institutions (e.g. NRL Formal Reports).

### 5.2. Before World War I.

Quinan, J.H. "Echo-Fringe Method for Detecting Icebergs," Hydrographic Bull. 13 May 1914.

"Submarine Detector," U.S. Nav. Inst. Proc. 20 (1894), 831-832.

### 5.3. World War I Era.

#### 5.3.1. Organization for Research and Research Policy.

Griffin, R.S. History of the Bureau of Engineering, Navy Department, During the War. Washington: Navy Department, Records and Library Historical Section Publication Nr. 5, 1922.

Millikan, Robert A. "Contributions of Physical Science," in Yerkes, R.M. ed., The New World of Science: Its Development during the War. New York: Century, 1920, 33-49.

Scott, Lloyd N., Naval Consulting Board of the United States. Washington: Navy Department, 1920.

#### 5.3.2. Underwater Acoustics.

Moorecrott, J.H. "Supersonics: Historical Survey of Development in the United States," 21 October 1918. Unpublished paper presented at Inter-Allied Conference, Paris. Copy in Naval Engineering Experiment Station records, Folder 66.

Wills, A.P., Pupin, M.I., and others. "Supersonics", Dec. 1918-Jan. 1919. Unpublished reports, copies of which are in the NRC archives, the Naval Engineering Experiment Station records, and the NRL Historical Files.

### 5.3.3. Submarine Detection: Acoustic Devices and Techniques.

Anderson, J.A. and others. "Summary of a Study of the Langevin Supersound Source Projector," 1 April 1918. Unpublished report in archives of the National Research Council (NRC).

Bridgman, Paul. "Lectures on Anti-Submarine Devices," 1918. Nav. Eng. Exp. St. records, Folder 126-2.

Compton, K.T. "Submarine Signalling by Supersonics and the Detection of Submarines by Echo," 19 May 1918. Unpublished report of the Scientific Attache to the American Embassy, Paris, in Nav. Eng. Exp. St. records, Folder 66A.

Crandall, I.B. "High-Frequency Directive Submarine Signalling," 10 June 1918. Unpublished report in NRC archives.

Crandall, I.B. "Notes on Rochelle Salt Piezo Crystals", 23 July 1918. Unpublished report in NRC archives.

"Crystal Detectors and Their Uses". Transcript and reports from a Conference on Submarine Detection sponsored by the Committee on Physics and Engineering, NRC. Unpublished manuscript in NRC archives.

"Edison Submarine Detector," U.S. Nav. Inst. Proc. 44 (1918), p. 2382.

Hayes, Harvey C. "Detection of Submarines," Proc. Am. Phil. Soc. 59 (1920), 1-47. (Survey of American efforts in submarine detection during World War I.)

"Historical Resume of Tripod Studies." Undated, unpublished report pertaining early effort to establish fixed, coastal listening stations, in Nav. Eng. Exp. St. records, Folder 107-3.

Millikan, R.A. "Listening Devices". Unpublished report to General Board of the Navy, in archives of the NRC.

Moffett, Cleveland. "Fessenden Oscillator to Detect Submarines," Electrical Review and Western Electrician 66 (17 Apr 1915), pp. 738-739.

Morecroft, J.H. "Report on Supersonic Apparatus developed by Professor Langevin and Method of Using It," 5 Nov 1918. Unpublished report in Nav. Eng. Exp. Station records, Folder 66B.

Nicolson, A. McL. "The Piezo-Electric Effect in Composite Rochelle Salt Crystals," 1918 (?). Manuscript report in Nav. Eng. Exp. St. records, Folder 2-6.

Quimby, S. L. "Data on Apparatus Used in ASDIC Research," Aug 1919. Unpublished report in Nav. Eng. Exp. St. records, Folder 66B.

Rutherford, Ernest. Untitled series of lectures on underwater sound and the application of sound to submarine detection, delivered at the Naval Engineering Experiment Station, 15 May-4 June 1917. Copies in Nav. Eng. Exp. St. records, Folder 66.

#### 5.3.4. Submarine Detection: Non-acoustic Devices and Techniques.

Bauer, L.A. "Report on Magnetic Detection of Submarines by the Department of Terrestrial Magnetism, Carnegie Institution, Washington," 3 Sept 1918. Unpublished report in NRC archives.

Parker, Herschel C. and Hatch, Edwin G. "Apparatus for Detecting and Destroying Submarines, Mines and the Like [Using an Undersea Searchlight]". U.S. Patent 1,172, 306. Application filed 26 Feb 1915. Patent granted 22 Feb. 1916.

\_\_\_\_\_. "Undersea Light," undated (probably late 1917 or early 1918). Unpublished report submitted to Submarine Signal Company, in Nav. Eng. Exp. St. records, Folder 56.

Pickering, Edward C. "Detecting Submarines by Visual Means, using the Nicol Prism," 1917. Unpublished report in Nav. Eng. Exp. Station records, Folder 68.

Secor, H.W. "Locating Hidden Submarines by Radio," Electrical Experimenter 5 (Dec 1917), pp. 509-510, 572.

Strong, R.M. "Report to the National Research Council on the Use of Seagulls in Locating Submarines," 14 Dec. 1917. Unpublished report in NRC archives, File: Comm. Physics: Submarine Detection: Reports, 1917.

#### 5.4. Inter-War Era, 1919-1939.

##### 5.4.1. Organization for Research.

"The Navy and Scientific Research and Experiment (Antisubmarine)," Engineering 8 June 1928, p. 687.

##### 5.4.2. Underwater Sound.

Bergmann, L. Ultrasonics and Their Scientific and Technical Applications. New York: John Wiley and Sons, 1939.

Dorsey, H.G. "Transmission of Sound through Sea Water," Journ. Acoustical Soc. Am. 3 (1932), 428-442.

Eckhardt, E.A. "Accurate Determinations of the Speed of Sound in Sea Water," Physical Review 24 (1924), 452-455.

Eve, A.S. "Problems in Underwater Acoustics," Journ. Franklin Inst. 202 (1926), 627-635.

Heck, H.H., and Service, J.H. "Velocity of Sound in Sea Water," U.S. Coast and Geodetic Survey Sp. Publ. No. 108, 1924.

Hubbard, J.C. "Brief Survey of Supersonics," Journ. Acoust. Soc. Am. 4 (1932), 99-107.

Jones, A.T. Sound. New York: Van Nostrand, 1937.

Klein, Elias. "Absolute Sound Measurements in Liquids," Journ. Acoustical Soc. Am. 10 (1938), 105-123.

Olson, H.F., and Massa, F. Applied Acoustics. Philadelphia: Blakiston, 1939.

Richards, William T. "An Intensity Gauge for Supersonic Radiation in Liquids," Proc. Nat. Acad. Sci. 15 (1929), 310-312.

\_\_\_\_\_. "Recent Progress in Supersonics," Journ. Acoustical Soc. Am. 9 (1938), 273-281.

Stephenson, E.B. Absorption Coefficients of Sound in Sea Water. Washington: NRL, NRL Report S-1466, 12 Aug 1938.

\_\_\_\_\_. Absorption Coefficients of Supersonic Sound In Open Sea Water. Washington: NRL, NRL Report S-1549, 2 Aug 1939.

\_\_\_\_\_. Transmission of Sound in the Sea. Washington: NRL, NRL Report S-1204, 16 Oct 1935.

\_\_\_\_\_. "Velocity of Sound in Sea Water," Physical Review 21 (1923), 181-185.

Swainson, O.W. "velocity and Ray Paths of Sound Waves in Sea Water," Hydrographic Review 14 (1937), 93-153.

Wolff, I. and Malter, L. "Directional Radiation of Sound," Journ. Acoustical Soc. Am. 2 (1930), 201-212.

Wood, Alexander. Sound Waves and Their Uses. London: Blackie, 1930.

Wood, R.W. Supersonics. Providence, R.I.: Brown Univ. Press, 1939.

#### 5.4.2. Related Research--Hydrography and Oceanography.

"Echo Sounding," Hydrographic Review II (1924), 51-91, 135-192; III (1926), 75; V (1928), 131-165; VII (1930), 105-113; VIII (1931), 168-185; IX (1932), 135; XI (1934), 25-62; XIV (1937), 111-128.

Hayes, Harvey C. "The Application of Acoustics to Submarine Surveying," Geographical Review 14 (1924), 681-694.

\_\_\_\_\_. "Measuring Ocean Depths by Acoustic Methods," Hydrographic Review II (1924), 93-121.

\_\_\_\_\_. "The Sonic Depth Finder," Proc. Am. Phil. Soc. 63 (1924), 134-151.

\_\_\_\_\_. "Research Work in the Navy--Extension to the Study of Oceanography," a Proposal to the Navy Hydrographic Office and the National Research Council, 19 Feb 1923. Copy in NRC archives File, Exec. Comm, 1919-1924: Gov't Agencies (Navy).

Hubbard, B.R. "Position Finding by Underwater Sound Signals," Journ. Acoustical Soc. Am. 4 (1932), 138-154.

Iselin, C. O'D. "Some Phases of Modern Deep-Sea Oceanography," Smithsonian Report for 1932, Washington: Smithsonian Inst., 1933, 251-267.

MacMillan, D.H. "Echo Sounding in Harbor Hydrography," U.S. Coast and Geod. Surv. Field Engineers Special Publication 12 (1938), 136-141.

Smith, P.A. "Recent Acoustic Work of the U.S. Coast and Geodetic Survey," U.S. Coast and Geodetic Survey Field Engineers Special Publication 8 (1934), 60-75.

Spilhaus, Athelstan F. "A Bathythermograph," Journ. Marine Research 1 (1938), 95-100.

#### 5.4.3. Submarine Detection: Acoustic Devices and Techniques.

Hayes, Harvey C. Development of Electrodynamic Type of Underwater Sound Projector. Washington: Naval Research Laboratory, NRL Report S-1514, Feb. 1939.

\_\_\_\_\_. Report on Sound Research and Development with Particular Reference to Tests on the USS SEMMES. Washington: Naval Research Laboratory, NRL Report S-1404, Oct. 1937.

\_\_\_\_\_. Test of Model QB Underwater Sound Equipment of the U.S.S. Cuttlefish. Washington: Nav. Res. Lab., NRL Report Nr. S-1078, 5 Oct 1934.

\_\_\_\_\_. Test of the QC Equipment of the U.S.S. Farragut. Washington: Nav. Res. Lab., NRL Rpt. Nr. S-1084, 12 Oct 1934.

\_\_\_\_\_. "United States Hydrophones," Proc. Am. Phil. Soc. 59 (1920), 371-404.

Hund, A. "Uses and Possibilities of Piezoelectric Oscillators," Proc. Inst. Radio Eng. 14 (1926), 447-461.

Mason, Ma. . "Submarine Detection by Multiple Unit Microphones," Wisconsin Eng. 25 (1921), 75-77, 99-102.

Steinberger, R.L. Underwater Sound Investigation in Northern Waters. Washington: Navy Yard, 25 Jan 1938.

Webb, R.B. "Determination of Azimuth by Means of the Binaural Sense," Coast Artillery Journ. 59 (1923), 17-34.

Wilson, H.A. "The Theory of Receivers for Sound in Water," Physical Review 15 (1920), 178-205.

#### 5.4.4. Submarine Detection (Non-Acoustic).

Whitehead, J.B. and Grondahl, L.O., . "Submarine Detection in an Alternating Magnetic Field," Journ. Inst. Elect Eng. 39 (Mar. 1920), pp. 223-224, 381-395.

## 5.5. World War II Era.

### 5.5.1. Organization for Research and Research Policy.

Colpitts, E.H. "Scope of Division Activities," in A Survey of Subsurface Warfare in World War II, Summary Technical Report of Division 6, NDRC, Vol. I, Washington: Office of Scientific Research and Development, 1946, 21-25.

Harvard University Underwater Sound Laboratory. Harvard-NDRC Underwater Sound Project: Prospectus and Outline. Cambridge, 15 Aug 1941.

Herrick, John. Subsurface Warfare: The History of Division 6, NDRC. Washington: Department of Defense, 1 January 1951.

Hutchisson, Elmer. "Organization of the Subsurface Warfare Group," in Survey of Subsurface Warfare, 26-74.

Knudson, O. Brief Progress Report on the NDRC Project at Point Loma. San Diego: University of California Division of War Research (OEMsr-30), 20 Aug 1941.

Morse, Phillip M. "The Antisubmarine Problem," "The Role of Operations Research in Anti-Submarine Warfare," "NDRC Background," "Development of U.S. Operations Research," and "Research Activities," in Survey of Subsurface Warfare, 7-20, 75-118.

Operations Research Gp./U.S. Fleet. A Summary War History of the Submarine Operations Research Gp. ORG Report 50. Washington: Navy Department/Office of Chief of Naval Operations, 1 October 1945.

"Report of Subcommittee on the Submarine Problem to the Naval Research Advisory Committee of the National Academy of Sciences," ("Colpitts Report"), E.H. Colpitts, Chairman, 28 January 1941. Original in NRC archives.

### 5.5.2. Underwater Sound.

Camp, Glen D. and Eckart, Carl. Some Theoretical Studies of the Propagation of Sound in Shallow Water. NDRC 6.1-sr30-1208, Rpt. U-102, UCDWR, 15 Aug 1943.

Eckart, Carl. The Attenuation of Sound in the Sea. NDRC 6.1-sr30-1532, Service Project NS-140, Rpt. U-236, UCDWR, 6 July 1944.

\_\_\_\_\_, "Fundamental Studies of Underwater Sound," in Survey of Subsurface Warfare, 119-143.

Everest, Frederick A., and O'Neill, H.T. Attenuation of Underwater Sound. NDRC C4-sr30-494, UCDWR, 30 July 1942.

Ewing, Maurice, and Worzel, J. Lamar. Long Range Sound Transmission. Woods Hole Oceanographic Institute, 25 August 1945.

Hartmann, G.K. and Focke, Alfred B., "Absorption of Supersonic Waves in Water and Aqueous Suspensions," The Physical Review 57 (1940), 221-244.

Hunt, Frederick V. Applied Acoustics in Subsurface Warfare, Final Report for Contracts OEMsr-58 and OEMsr-287, 1941-1946, Issued as OSRD Rpt. Nr. 6658, 31 January 1946.

Ide, J.M., and others. The Propagation of Underwater Sound at Low Frequencies as a Function of the Acoustic Properties of the Ocean Bottom. Washington: NRL, NRL Report S-2113, 15 Aug 1943.

Iselin, C. O'D. Preliminary Report on Prediction of "Afternoon Effect". NDRC C4-sr31-137, 25 July 1942.

Pekeris, Chaim L. Theory of Diffraction of Sound in the Shadow Zone. NDRC 6.1 sr20-846, CUDWR, 5 May 1943.

\_\_\_\_\_, Theory of Propagation of Explosive Sound in Shallow Water. OSRD 6545, NDRC 6.1 sr1131-1891, CUDWR, January 1945.

Physics of Sound in the Sea. Summary Technical Rpt., NDRC Div. 6, Vol. 8, 1946. Part I: Bergamann, P.G. and others, Transmission; Part II: Spitzer, Lyman, Reverberation; Part III: Spitzer, Lyman, Reflection of Sound from Submarines and Surface Vessels; Part IV: Wildt, R., Acoustic Properties of Wakes.

Principles and Applications of Underwater Sound. Summ. Tech. Rpt., NDRC Div. 6, Vol. 7.

Woods Hole Oceanographic Institute. Sound Transmission in Sea Water. WHOI Rpt. G1/1184, 1 Feb 1941.

Woollard, G.P. Factors affecting Long Distance Sound Transmission in Sea Water. OSRD 1505, 30 Mar 1943.

### 5.5.3. Related Studies -- Oceanography.

Holter, N.J. Measurements of the Horizontal Thermal Structure of the Ocean. Report S-17, U.S.N. Radio and Sound Lab., 18 Aug 1944.

Military Oceanography. Summary Technical Report, NDRC, Division 6, Vol. 6A, 1946.

Spilhaus, Athelstan F. "A Detailed Study of the Surface Layers of the Ocean in the Neighborhood of the Gulf Stream," Journ. Marine Res. 3 (1940), 51-75.

Sverdrup, H.U., and others. The Oceans. New York: Prentice-Hall, 1942.

University of California Division of War Research. Some Characteristics of the Sound Field in the Sea. OSRD 546, 13 Mar 1942.

#### 5.5.4. Submarine Detection: Acoustic Devices and Techniques.

ASW Operations Research Gp./Tenth Fleet. Underwater Listening and Echo Ranges. Research Rpt. 80, 16 Dec 1944.

Bell Telephone Labs. The Sound Spectrograph, A Time-Frequency-Intensity Analyzer. Contractor's Report per contract OEMsr-435, 1 Oct 1943.

Coleman, John S. "Anti-Submarine Detection Equipment," in Survey of Subsurface Warfare, 177-197.

Hayes, Harvey C. An Analysis of the Anti-Submarine Warfare Problem from the Standpoint of Underwater Acoustics. Washington: USNRL, NRL Rpt. Nr. S-1908, 17 July 1942.

Hebb, Malcolm H. and Brooks, Harvey. Magnetostrictive Transducers. Washington: NDRC 6.1-sr287-898, HUSL, 22 June 1943.

Shankland, Robert S., and others. "Transducer Research and Calibration," in Survey of Subsurface Warfare, 144-160.

Stephenson, E.B. Comparative Tests of the QC, JK and JL Listening Gear. Washington: USNRL, NRL Rpt. No. S-1610, 19 Apr 1940.

University of California Division of War Research. The Sound Field of Echo-Ranging Gear. UCDWR Rpt. U-113, OSRD 2011, 1 Oct 1943.

#### 5.5.5. Submarine Detection: Non-acoustic Devices and Techniques.

Gulf Research and Development Co. Application of Sensitive Magnetic Devices to Detection of Submarines from Aircraft. OSRD 1870, 1 July 1942.

Hull, Albert W. "Development of Devices for Detecting Submarines by Magnetic Effects," in General Electric Company, Report of Work on Contract OEMsr-34 (Final Technical Report). OSRD 1042, 24 Oct 1942.

Kinsler, L.E. "Imaging of Underwater Objects," Am. Journ. Physics 13 (1945), 255-257.

Lathrop, J.E. "Performance of Electromagnetic Techniques in World War II," Paper Nr. 6, NAS-NRC-NAVY Symposium on Undersea Warfare, 18 September 1946.

McKinley, W.D. "Note on Detection of Undersea Craft by Means of Low Frequency Radiation from Aircraft," Canadian Journ. Research 23 (1945), 77-85.

Magnetic Airborne Detection Equipment. OSRD Report 5486, 15 July 1945.

Mannal, C., and Wade, Elmer J. Detection of Underwater Craft by Means of Short Pulses of Light. OSRD 1400, undated.

Osgood, Thomas H., and Palmer, R.R. The Magnetic Airborne Detector. OSRD 1124, 19 Dec 1942.



## 6. PRINCIPAL CONTRACTORS AND RESEARCH FACILITIES.

### 6.1. Before World War I.

Electric Boat Company, New London, Connecticut.

Submarine Signal Company, Boston, Mass.

U.S. Coast and Geodetic Survey.

U.S. Navy, Hydrographic Office.

U.S. Navy, Torpedo Station, New London, Connecticut.

### 6.2. World War I Era.

Carnegie Institution, Washington, D.C.

Columbia University.

Electric Boat Company, New London, Connecticut.

General Electric Company, Research Laboratory, Schenectady, N.Y.

Harvard University.

Lake Torpedo Boat Company, Bridgeport, Connecticut.

National Electric Signalling Company (Westinghouse), Pittsburgh, Penna.

Submarine Signal Company, Boston and Nahant, Mass.

U.S. Navy, Engineering Experiment Station, New London, Connecticut.

University of Chicago.

Western Electric Company, Research Laboratory, New York City, N.Y..

### 6.3. Inter-War Era, 1919-1939.

Bell Telephone Laboratories (Western Electric), New York City, N.Y.

General Electric Company, Electric Boat Division, New London, Connecticut.

General Electric Company, Research and Development Labs., Schenectady, N.Y.

Submarine Signal Company, Boston and Nahant, Mass., and Portsmouth, R.I.

U.S. Navy, Naval Research Laboratory, Washington, D.C.

U.S. Navy, Navy Yard Model Basin, Washington Navy Yard, D.C.

Woods Hole Oceanographic Institute, Woods Hole, Mass.

### 6.3. World War II Era.

Bell Telephone Laboratories (Western Electric), New York City, N.Y..

California Institute of Technology, Pasadena, Calif.

Columbia University, Division of War Research.

General Electric Company, Research and Development Laboratories,  
Schenectady, NY.

Gulf Research and Development Company, Pittsburgh, Penna.

Harvard University, Underwater Sound Laboratory.

Massachusetts Institute of Technology, Cambridge, Mass.

RCA Manufacturing Company, Camden, N.J.

U.S. Navy, David W. Taylor Model Basin, Carderock, Maryland.

U.S. Navy, Naval Research Laboratory, Washington, D.C.

U.S. Navy, Radio and Sound Laboratory, San Diego, Calif.

U.S. Navy, Underwater Sound Reference Laboratory.

Western Electric Company, New York City, N.Y.

Woods Hole Oceanographic Institute, Woods Hole, Mass.